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Extended essay cover

Diploma Programme subject in which this extended essay is registered: World Studies

(For an extended essay in the area of languages, state the language and whether it is group 1 or group 2.)

Title of the extended essay: What are the economic costs associated with obesity and how can authorities best measure it, in order to combat it. A Case Study of the U.S..

Candidate's declaration

This declaration must be signed by the candidate; otherwise a grade may not be issued.

The extended essay I am submitting is my own work (apart from guidance allowed by the International Baccalaureate).

I have acknowledged each use of the words, graphics or ideas of another person, whether written, oral or visual.

I am aware that the word limit for all extended essays is 4000 words and that examiners are not required to read beyond this limit.

This is the final version of my extended essay.

Supervisor's report and declaration

The supervisor must complete this report, sign the declaration and then give the final version of the extended essay, with this cover attached, to the Diploma Programme coordinator.

Name of supervisor (CAPITAL letters)

Please comment, as appropriate, on the candidate's performance, the context in which the candidate undertook the research for the extended essay, any difficulties encountered and how these were overcome (see page 13 of the extended essay guide). The concluding interview (viva voce) may provide useful information. These comments can help the examiner award a level for criterion K (holistic judgment). Do not comment on any adverse personal circumstances that may have affected the candidate. If the amount of time spent with the candidate was zero, you must explain this, in particular how it was then possible to authenticate the essay as the candidate's own work. You may attach an additional sheet if there is insufficient space here.

embraced the concept of the Extended Essay with enthusiasm and pursued her research question with a great deal of independence.
We met regularly to discuss her progress and she would come to these meeting prepared and with new ideas.
struggled to obtain appropriate data to use in her research and her pursuit of many fruitless leads delayed her progress to an extent. She persevered and eventually found an appropriate data set through the internet.
As mathematical modeling is no longer addressed through Internal Assessment, the student was required to self-teach this component and that of Least Squares regression.
It has been a pleasure working with on this project; one I feel she has truly embraced in its intended spirit and will serve her well in her future studies.

This declaration must be signed by the supervisor; otherwise a grade may not be issued.

I have read the final version of the extended essay that will be submitted to the examiner.

To the best of my knowledge, the extended essay is the authentic work of the candidate.

I spent [4·5] hours with the candidate discussing the progress of the extended essay.

Assessment form (for examiner use only)

Criteria	Achievement level				
	Examiner 1	maximum	Examiner 2	maximum	Examiner 3
A research question	2	2		2	
B introduction	1	2		2	
C investigation	3	4		4	
D knowledge and understanding	3	4		4	
E reasoned argument	4	4		4	
F analysis and evaluation	3	4		4	
G use of subject language	4	4		4	
H conclusion	2	2		2	
I formal presentation	4	4		4	
J abstract	2	2		2	
K holistic judgment	3	4		4	
Total out of 36	31				

World Studies Extended Essay

What are the economic costs associated with obesity, and how can authorities best measure obesity in order to combat it?

A Case Study of the United States

Candidate:
Candidate Number:

Word Count: 3996

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Abstract

Obesity is no longer the problem of an individual's health, in fact, it is the fifth leading risk for deaths globally[1]. Governments are affected by the increase of the consumption of manufactured and processed foods. This lead to an increase in obesity rates in the US and China, for example, and to an increase in indirect and direct health care costs.

In order to obtain meaningful obesity rates, a model with higher degrees of reliability and validity, than the current BMI ($=\frac{weight(kg)}{height^2(m)}$), must be used. The research question, **What are the economic costs associated with obesity, and how can authorities best measure obesity in order to combat it?** aims at emphasizing the importance of rising obesity today and attempts to explain why the current BMI model has to be replaced, by suggesting a more accurate model of measuring obesity rates on our planet.

This was done by using figures of economic costs in China and the US, and furthermore supported by theory, to show that obesity results from a market failure. Height(m) and weight(kg) values, used from a database were plotted on graphs with ranges from both formulas, to show where the current formula is limited. Prof.N.Trefethen's suggestion of a new BMI formula was used to prove that it is a preciser model for measuring obesity.

In conclusion, Obesity brings on secondary costs, to those suffering from it, and to society. Obesity is costly, but preventable. The BMI analysis; the current model is limited in accuracy due to too many assumptions made. Trefethen's model fits the data better, as it is less limited. However, there is no BMI-model that matches all body types. Thus, it was recommended for each country to decide on their own interpretations of BMI ranges to best suit the body proportions in their country.

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[1] "Obesity and Overweight." *WHO*. N.p., n.d. Web. 02 Nov. 2013. <http://www.who.int/mediacentre/factsheets/fs311/en/>.

Introduction

Obesity has become one of the most widespread health conditions on a global scale([2]). The World Health Organization(WHO) states that obesity is the fifth leading risk for deaths globally[3]. An increase in the consumption of manufactured fast food in the past 30 years in the United States, has lead to an escalation of obesity rates within the country, leading to an increase in indirect and direct health care costs. The U.S. is the second fattest country in the world after Mexico[4], with currently 35.7% of adults considered obese according to the Centers for Disease Control and Prevention[5], meaning more than 1/3 Americans are obese. Obesity brings on secondary costs, to not only those suffering from it, but also to society. The Institute for America's Health states that health care costs associated with obesity have soared from $3.6billion to $36.5billion from 1987 until today[6]. It has been estimated that approximately 61% of the total health care costs in the U.S. result from obesity related illnesses, diseases and health problems today[7]. Although high rates of obesity in the U.S. mainly resulted from over-consuming processed manufactured food, the roots of the problem also lie in sedentary lifestyles which have increased along with technology advancements. Furthermore many developing countries which are now experiencing rapid economic growth are beginning to face the health problems associated with the consumption of high-saturated fat, high-carbohydrate diets. For example in China, the number of overweight and obese people below the

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2 "The Heterogeneity of the Cigarette Price Effect on Body Mass Index." *The Heterogeneity of the Cigarette Price Effect on Body Mass Index*. N.p., n.d. Web. 05 Nov. 2013. <http://www.sciencedirect.com/science/article/pii/S0167629612000720>.

3 "Obesity and Overweight." *WHO*. N.p., n.d. Web. 02 Nov. 2013. <http://www.who.int/mediacentre/factsheets/fs311/en/>.

4 "Mexico Takes Title of "most Obese" from America." *CBSNews*. CBS Interactive, n.d. Web. 02 Apr. 2013. <http://www.cbsnews.com/8301-202_162-57592714/mexico-takes-title-of-most-obese-from-america/>.

5 Begley, Sharon. "Fat and Getting Fatter: U.S. Obesity Rates to Soar by 2030." *Reuters*. Thomson Reuters, 18 Sept. 2012. Web. 02 Nov. 2013. <http://www.reuters.com/article/2012/09/18/us-obesity-us-idUSBRE88H0RA20120918>.

6 "Facts, Stats, and Quotes on Obesity In America." *IAH*. N.p., n.d. Web. 02 Aug. 2013. <http://healthy-america.org/facts-stats-and-quotes-on-obesity-in-america/>.

7 "Obesity and the Rising Cost of Healthcare in America." *Fair Food Network*. N.p., n.d. Web. 02 Apr. 2013. <http://www.fairfoodnetwork.org/connect/blog/obesity-and-rising-cost-healthcare-america>.

age of 18 has already reached 120million[8], resulting in a healthcare cost bill of $3.3billion USD[9]. In China, the popularity of Western-style foods have increased among young children and adolescents, and over 80% of adults have abandoned physical activity[10]. Obesity is not only a rich country disease, but a global problem.

In order to find these figures, the standard measurement method used is the Body Mass Index formula. There are four categories to consider: underweight - normal weight - overweight - obese, which are used to determine the physical status of a person. Cultural backgrounds and genetic compositions can lead to anomalies in the BMI calculations, thus, Singapore and the US have changed their BMI ranges. For example, in the U.S. a person with a BMI of 30 is obese([11]); whereas in Singapore, a person with similar symptoms has a BMI of 25.

Given that countries are using this formula to calculate obesity costs, the extent to which the calculations is accurate is imperative to consider. Are there limitations to the BMI model, and is it the accurate way to measuring obesity?

This leads to the research questions "**What are the economic costs associated with obesity in the United States, and how can authorities best measure obesity in order to combat it?**".

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[8] "Obesity Is a Growing Concern in China." - *China.org.cn*. N.p., n.d. Web. 04 Apr. 2013. <http://www.china.org.cn/china/2012-09/14/content_26521029.htm>.

[9] Ibid.

[10] Ibid.

[11] "Success4Dummies.com » Blog Archive » Obesity: Environmental Or Genetic? By Mohammed Hasan." *Success4Dummiescom RSS*. N.p., n.d. Web. 06 June 2013. <http://www.success4dummies.com/2009/07/21/obesity-environmental-or-genetic-by-mohammed-hasan/>.

What causes Obesity?

Obesity and Overweight occur over a long period of time, often caused by a lack of energy balance[12], according to the National Heart, Lung and Blood Institute. A lack of energy balance is when the energy intake exceeds the energy your body uses[13].

In the U.S., an increasingly amount of people experience this 'lack of energy balance' over a longer period of time, leading to increasing obesity rates within their country.

According to Alyssa Brown, the obesity rates in the US have soared from 25.5% in 2008 to 26.2% in 2012[14]. Furthermore, the Food Research & Action Center states that 68.8% of adults are overweight or obese, with an additional 35.7%[15], who are obese. Additionally, the WHO states that the obesity rates has nearly doubled since 1980[16]. Not only have the obesity rates soared due to their lack of energy balance, but also because of the nature of food production that is present in the market place of today. The type of food that contains excessive amounts of carbohydrates and saturated fats are found at a much higher content level in fast foods (demerit goods[17]) rather than in healthy food. Needless to say, the cost of fast food is by far cheaper than 'healthy' products, and the tendency for the lower-income households to purchase low cost food, is high.

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12 "What Causes Overweight and Obesity?" - *NHLBI, NIH*. N.p., n.d. Web. 29 Oct. 2013. <http://www.nhlbi.nih.gov/health/health-topics/topics/obe/causes.html>.

13 Ibid.

14 "In U.S., Obesity Rate Stable in 2012." *In U.S., Obesity Rate Stable in 2012*. N.p., n.d. Web. 29 Oct. 2013. <http://www.gallup.com/poll/160061/obesity-rate-stable-2012.aspx>.

15 Begley, Sharon. "Fat and Getting Fatter: U.S. Obesity Rates to Soar by 2030." *Reuters*. Thomson Reuters, 18 Sept. 2012. Web. 02 Nov. 2013. <http://www.reuters.com/article/2012/09/18/us-obesity-us-idUSBRE88H0RA20120918>. Op.cit.

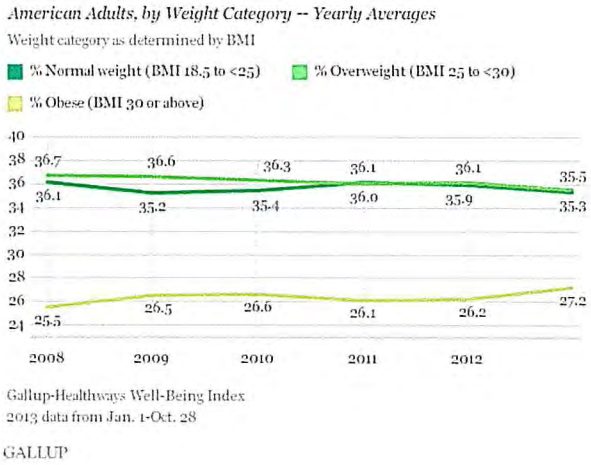
16 "Obesity and Overweight." *WHO*. N.p., n.d. Web. 02 Nov. 2013. <http://www.who.int/mediacentre/factsheets/fs311/en/>. Op.cit.

17 Demerit goods are goods, whose production and/or consumption are harmful to a society; individually and as a whole.

Obesity: The result of a Negative Externality of Consumption

According to the article *The Cost of Obesity*, obesity rates in the U.S. has rocketed from 13% to 34% in the past 50 years[18], while the percentage of Americans who are "morbidly" obese, has soared from 0.9% to 6%[19]. This quote apprises that not only have the obesity rates within the US increased, but also the percentage of already obese people. These figures were calculated using the BMI formula, which, according to the WHO, is defined as $\frac{weight(kg)}{height(m)^2}$, and a BMI value equal to or above 30 is classified as obese[20].

Table 1: showing the yearly averages of the BMI values in percentage of people in the US who are in the normal weight, overweight or obese range.



Source: "U.S. Obesity Rate Climbing in 2013." U.S. Obesity Rate Climbing in 2013. N.p., n.d. Web. 03 Sept. 2013. <http://www.gallup.com/poll/165671/obesity-rate-climbing-2013.aspx>.

Table 1 reveals a remarkable increase in the obesity rates over the past 7 years. From 2008 to 2010 the percentage of obesity has increased, from 25.5% to 26.6%, whereby it fell by 0.5% from 2010 to 2011, and slowly increased again from 2011 to 2013, by 1.1%. Overall the obesity rates has increased since 2008 by 1.7%, resulting in higher needs to tackle direct and indirect health care costs caused by obesity. In hospitals for example, the costs for gastric bypass surgeries have soared from $13,386USD in 1998 to $220,000USD in 2008, to simply handle heavier patients[21]. Overall it has been estimated that $190billionUSD are annually spent on medical costs due to obesity[22]. A lot of spending by the government contributed to a preventable issue, resulting in an opportunity cost; the government could

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[18] Reuters. "The Costs Of Obesity." *The Huffington Post*. TheHuffingtonPost.com, 30 Apr. 2012. Web. 12 Sept. 2013. <http://www.huffingtonpost.com/2012/04/30/obesity-costs-dollars-cents_n_1463763.html>.

[19] Ibid.

[20] "Obesity and Overweight." *WHO*. N.p., n.d. Web. 05 Sept. 2013. <http://www.who.int/mediacentre/factsheets/fs311/en/>. op.cit.

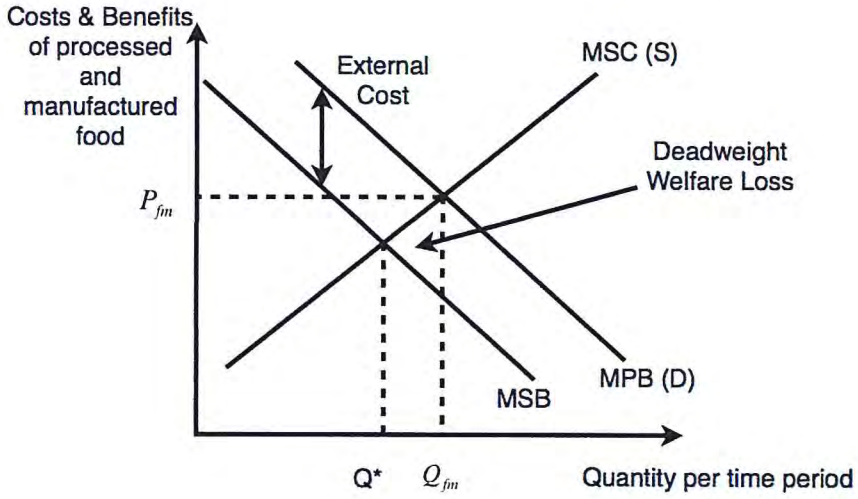
[21] *Forbes*. Forbes Magazine, n.d. Web. 03 Feb. 2013. <http://www.forbes.com/sites/bethhoffman/>.

[22] Reuters. "The Costs Of Obesity." *The Huffington Post*. TheHuffingtonPost.com, 30 Apr. 2012. Web. 03 Feb. 2013. <http://www.huffingtonpost.com/2012/04/30/obesity-costs-dollars-cents_n_1463763.html>. Op.cit.

have used the spending on these expensive medical-care cost, on other projects, such as education for children and adolescents or infrastructure. This investigation on the costs brought about by obesity shows that obesity in the U.S. creates third-party external costs. This means that those who are not classified as obese, still have to pay for those who are obese, the ones considered in the public health care system. Using a microeconomic model of the negative externalities of consumption, the costs and benefits of obesity can be interpreted. Approximately 61% of the overall health care costs result from obesity related illnesses[23]. The U.S. government decided to find solutions to decrease the obesity rates in their country. One main aspect to tackle, is the consumption of manufactured, processed food, as well as high-sugar- and saturated fat-content food. Thus, Diagram 1 shows the costs and benefits of consuming these types of goods, which are considered as demerit goods by the US government.

Diagram1: showing the negative externality of consumption created by the consumption of food types[24] that cause obesity.

Market for processed and manufactured foods[25] in the United States.



As shown on Diagram 1, consumers enjoy eating processed and manufactured foods, (MPB) Marginal Private Benefit. However, the Marginal Social Benefit (MSB), the benefit to society as a whole, is below the individual private benefit. In a free market, the equilibrium price and quantity for manufactured and processed food lies at P_{fm} and Q_{fm} respectively. In this free market equilibrium, the negative externalities, that is, the full external costs have not yet been taken into account. The upward sloping (MSC) Marginal Social Cost curve, represents the costs of obesity to society as a whole.
The costs of consuming processed and manufactured foods include indirect and direct costs. Examples of direct costs are preventive, diagnostic, and treatment services related to obesity[26]. Morbidity and Mortality

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[23] "Obesity and the Rising Cost of Healthcare in America." *Fair Food Network.* N.p., n.d. Web. 02 Apr. 2013. <http://www.fairfoodnetwork.org/connect/blog/obesity-and-rising-cost-healthcare-america>.

[24] manufactured, processed, high-sugary, high-saturated fat content foods.

[25] including high-sugary, high-saturated fat content foods.

[26] "Causes and Consequences." *Centers for Disease Control and Prevention.* Centers for Disease Control and Prevention, 27 Apr. 2012. Web. 03 Feb. 2013. <http://www.cdc.gov/obesity/adult/causes/index.html>.

costs, are part of the indirect costs. Morbidity costs are defined as the value of income lost[27] through decreased productivity, bed days, absenteeism and lost income[28]. Moreover the value of future income lost by premature death through mortality is also part of the indirect external costs[29]. The external costs to society is the distance between MSB and MPB.

When the full external costs are taken into consideration, the quantity of processed and manufactured foods would be at Q* from society's point of view. As the free market equilibrium fails to achieve the socially efficient level of output where MSB=MSC, consuming manufactured and processed foods results in a market failure. From society's point of view, there is an overconsumption of these goods and too many of economy's scarce resources have been allocated, leading to a misallocation of resources. Therefore, there is a deadweight welfare loss created due to the negative externalities of consumption, shown by the triangular area between MSC and MSB.

As well as in developed countries, such as the US, developing countries are also experiencing an increase in obesity rates. For example in China, overweight rates soared by nearly 40% from 1992 to 2002, while the obesity rates have nearly doubled, according to the Chinese Center for Disease Control and Prevention[30]. In 2003, direct costs associated with obesity in adults, has reached $3.3billionUSD[31]. The reasons for this increase in obesity rates, is due to the growing popularity and demand of "Western-style" food chains, as well as sedentary lifestyles. Additionally, chinese adults seem to have stopped physical activity; the latest measure shows that 83.3% of chinese adults have abandoned physical exercise[32]. Some experts state, that the reasons are the poor urban planning and conditions of cities in China. Prof. Chen Yuming stated, that people are "unable to find exercise venues nearby, people are inclined to go home and watch TV, while enjoying their snacks."[33]
Obesity in their country is rising and increases the burden on China's healthcare system[34]. According to McKinsey, China's health care spending is expected to rise from $357billion in 2011 to $1trillion in 2020[35]. The burden for developing countries to deal with the costs of obesity is higher, since fewer public health care systems and health care resources are available[36]. It is imperative to note, that obesity is not a health issue, it is a social issue, a global one.

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27 Ibid.

28 Ibid.

29 Ibid.

30 "Obesity Is a Growing Concern in China." - *China.org.cn*. N.p., n.d. Web. 05 Mar. 2013. <http://www.china.org.cn/china/2012-09/14/content_26521029.htm>. Op.cit.

31 Ibid.

32 Ibid.

33 Ibid.

34 Ibid.

35 Le Deu, Frank. "Insights & Publications." *Health Care in China: Entering 'uncharted Waters'* N.p., Nov. 2012. Web. 06 Oct. 2013. <http://www.mckinsey.com/insights/health_systems_and_services/health_care_in_china_entering_uncharted_waters>.

36 Ibid.

Mathematical Analysis of the current BMI model

The current formula, generally used, is:

$$\text{Body Mass Index} = \frac{weight(kg)}{height^2(m)}$$

The BMI is usually a value ranging from approximately 16.0 to 40.0. Within this range, there are sub-ranges, categories, which may determine ones physical status. The ranges of the values and the given category are shown below([37])

Ranges of BMI	Category
16.0 - 18.5	Underweight
18.5 - 25	Normal/Healthy weight
25 - 30	Overweight
30 - 35	Obese (moderately)
35 - 40	Obese (severely)

The BMI model is a mathematical model, therefore it does not apply to everyone specifically or to every type of body proportion. Mathematical modeling in general can help in providing a better analysis and could be derived in two different ways; the analytical or statistical. The analytical model is used to understand the nature of the data to suggest an appropriate model. The statistical model, on the other hand, uses statistical analysis to predict an appropriate model for the data, and is also termed as the stochastic model. In the analysis below, the statistical is used to best describe the data.
Several Scientists have been analyzing the formula and debating whether the dimensions chosen are sufficient, or whether other component should be taken into consideration. One of these scientists is Prof. Nick Trefethen, who is a professor of Numerics at the University of Oxford[38]. Prof. Nick Trefethen is a "highly cited researcher"[39], who won numerous prices for the best Mathematics articles from the years 2000 onwards. According to his Biography, he "is interested in the physics and mechanics of how bodies behave"[40]. He debated the BMI calculation to be the globally accepted formula and stated : "If all three dimensions of a human being scaled equally as they grew, then a formula of the form weight/height^3 would be appropriate. Fact is that they don't!"[41] With this sentence, he is trying to imply, that if the formula were based on a simple 3 dimensional model, then it would not match the BMI data at all. He suggested that the exponent should be 2.5, a number between the two dimensions. This is because

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[37] "How Four Stones of Extra Weight Can Take Three Years off Your Life." *Mail Online*. N.p., n.d. Web. 05 Oct. 2013. <http://www.dailymail.co.uk/health/article-1162737/How-stones-extra-weight-years-life.html>.

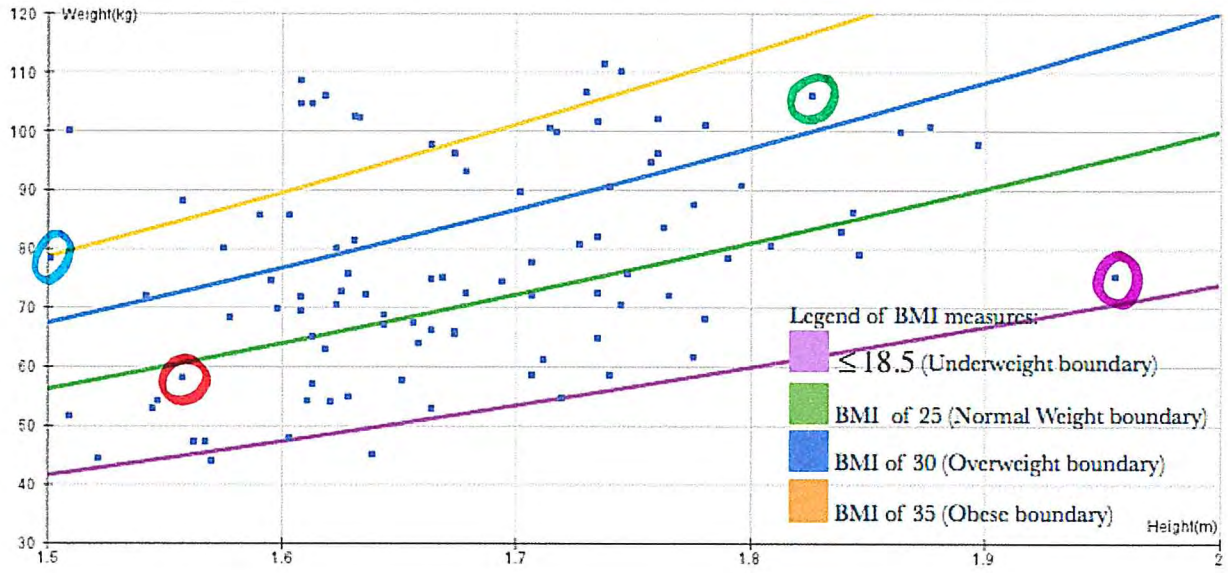
[38] "Does My BMI Look Big in This?" *News RSS*. N.p., 16 Jan. 2013. Web. 05 June 2013. <http://ox.ac.uk/media/science_blog/130116.html>.

[39] "Invited Speakers." *SNC 2007*. N.p., n.d. Web. 29 Oct. 2013. <http://www.orcca.on.ca/conferences/snc2007/site/talks/talks.html>.

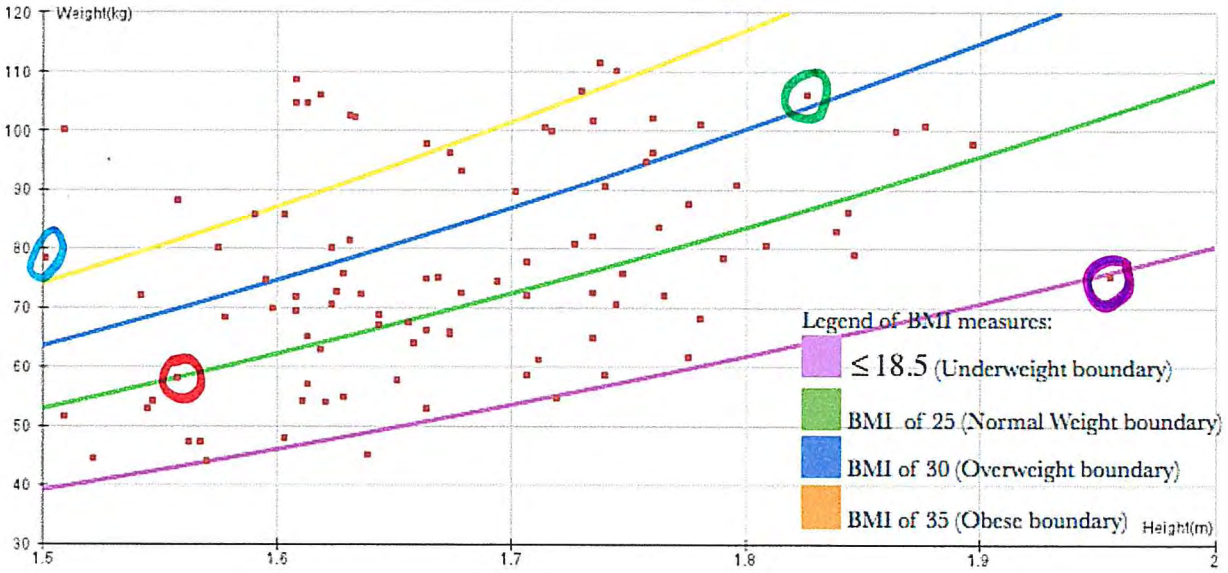
[40] Stephenson, Wesley. "BMI: Does the Body Mass Index Need Fixing?" *BBC News*. BBC, 29 Jan. 2013. Web. 29 Oct. 2013. <http://www.bbc.co.uk/news/magazine-21229387>.

[41] "Does My BMI Look Big in This?" *News RSS*. N.p., n.d. Web. 05 Aug. 2013. <http://www.ox.ac.uk/media/science_blog/130116.html>.

Graph 1: showing the interpretation of the ranges of the current BMI model, with 100 weight(kg) and height(m) values of US adults taken from http://www.statcrunch.com/app/index.php?dataid=304881[43].



Graph 2: showing the interpretation of the ranges of "the suggested BMI model", with 100 weight(kg) and height(m) values of US adults taken from http://www.statcrunch.com/app/index.php?dataid=304881[44].



[43] "StatCrunch." *StatCrunch*. N.p., n.d. Web. 04 Jan. 2013. <http://www.statcrunch.com/app/index.php?dataid=304881>.

[44] "StatCrunch." *StatCrunch*. N.p., n.d. Web. 04 Jan. 2013. <http://www.statcrunch.com/app/index.php?dataid=304881>. op.cit.

statistically, the data values (weight,height) have a better fit to a polynomial functions with a power of 2.5 than with a power 2. He gave his suggestion of the BMI model:

$$\text{BMI} = \frac{1.3 \times weight(kg)}{height^{2.5}(m)}$$

His main argument against the current BMI model, is that it "divides the weight by too large a number for short people and too small a number for tall people"[42]. Thus, tall people are deluded into thinking that they are bigger than they actually are and small people are misled into thinking that they are thinner than they are [43][44][45].

In order to address the application of Trefethen's theory and apply it to data available for this research, the data displayed below show the traditional BMI calculation and thereafter the suggested formula, in order to reflect on what he suggests to be a better BMI calculation.

[42] Stephenson, Wesley. "BMI: Does the Body Mass Index Need Fixing?" *BBC News*. BBC, 29 Jan. 2013. Web. 29 Oct. 2013. <http://www.bbc.co.uk/news/magazine-21229387>. Op.cit.

[43] Stephenson, Wesley. "BMI: Does the Body Mass Index Need Fixing?" *BBC News*. BBC, 29 Jan. 2013. Web. 29 Oct. 2013. <http://www.bbc.co.uk/news/magazine-21229387>. Op.cit.

[44] "Archive for the 'Health Law' Category." *Concurring Opinions RSS 20*. N.p., n.d. Web. 02 Nov. 2013. <http://www.concurringopinions.com/archives/category/health-law>.

[45] "Author Archive for Frank-pasquale." *Concurring Opinions RSS 20*. N.p., n.d. Web. 06 Aug. 2013. <http://www.concurringopinions.com/archives/author/Frank-Pasquale/page/2>.

At first, one might not see a significant difference between the two graphs. However, one major difference between the models lies in the distribution of the (height,weight) values along the BMI boundaries of the ranges. Two points with a height value ranging from 1.50m to 1.60m have been circled in both graphs, one with a weight close to 80kg, and the other is close to 60kg. In Graph 1, the point circled in blue lies exactly on the obese boundary function, thus this person has a BMI of 35. However in Graph 2, this same point lies above the obese boundary, indicating that the person actually has a BMI higher than 35. The second point within the height range, is circled in red in both graphs. In Graph 1, this point lies below the normal weight boundary, indicating that this person has a BMI lower than 25. Although in Graph 2, this same point lies exactly on the normal weight boundary, indicating that their BMI is exactly 25. A similar analysis accounts for the points circled in green and purple, which are between 1.80m and 2.00m tall. The green point is in the overweight range in both, Graph 1 and Graph 2. However, if one looks closely, that point is closer to the overweight boundary in Graph 2 than in Graph 1. This indicates that the person's BMI is higher than it should be; the person might think that they are bigger than they actually are. The last point circled in both graphs, is the purple one. In Graph 1, the purple point is in the normal weight range, a BMI above 18.5. However in Graph 2, this same point is below the underweight range, that is, below a BMI of 18.5.

These four points were chosen due to their upper and lower extreme values in height. The blue and the red circled points are short people; their height does not exceed 1.60m, whereas the green and purple point, are tall people, thus height values lie above 1.80m. From the analysis above, the blue and red points gain BMI units, whereas the purple and green points lose BMI units. This is what Trefethen's theory suggested; small people are misled into thinking that they are thinner than they really are, and tall people are misled into thinking that they are bigger than they actually are[48][49][50].

However, a more accurate method is needed to help determining which formula is more correct than the other. Therefore, it is essential to evaluate the residual values from both graphs.

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[48] Stephenson, Wesley. "BMI: Does the Body Mass Index Need Fixing?" *BBC News*. BBC, 29 Jan. 2013. Web. 29 Oct. 2013. <http://www.bbc.co.uk/news/magazine-21229387>. Op.cit.

[49] "Archive for the 'Health Law' Category." *Concurring Opinions RSS 20*. N.p., n.d. Web. 02 Nov. 2013. <http://www.concurringopinions.com/archives/category/health-law>.

[50] "Author Archive for Frank-pasquale." *Concurring Opinions RSS 20*. N.p., n.d. Web. 06 Aug. 2013. <http://www.concurringopinions.com/archives/author/Frank-Pasquale/page/2>.

Residuals & Best Fit of Data

Residuals are a useful tool in bivariate statistics and defined as "the sum of deviations from a best-fit curve of arbitrary form.[51]" The formula which best fits the data can be determined using calculated residuals. Both formulas, the current and Trefethen's suggestion of the BMI model have been used to calculate what weight(kg) each person from the database used would have, if they had a BMI that lay exactly on the mid-point of the normal range, i.e. (18.5+25)÷2; 21.75. The residuals were then calculated by subtracting their actual weight(kg) from the weight they would have with a BMI of 21.75, and then squaring that difference.

One of Trefethen's main issues about the current BMI formula is considering the height of the people. In order to see which formula fits the data best, quartiles have to be used to identify those of extreme heights. There is the lower quartile and the upper quartile which have to be considered. The lower quartile, Q_1 is defined "as the 25th percentile"[52] of a set of data, and the upper quartile as "the 75th percentile[53]". The difference between Q_3 and Q_1 is known as the **interquartile range**, and describes the distribution of a set of data around a central value, which in this case is a BMI of 21.75. Therefore, Q_1 can be taken as representative of the lowest 25% of the data by height, and Q_3 of the upper 25%.

Table 4: showing the sum and average of the lower and upper quartile values of the current and suggested BMI values from Table 1[54].

Sum of the residuals for a given quartile				
Quartile	**Current BMI formula**	Average/person	**Trefethen's BMI formula**	Average/person
Q1	14389.07	575.56	16001.41	640.06
Q3	16265.13	650.61	14353.10	574.12

The table shows us that the residuals for the lowest quartile, i.e. those people below the average height, are lower under the current model than they are under the suggested model. This confirms, that under the suggested model, they would move away from the normal range. Conversely, the residuals for the upper quartile, i.e. those people above the average height, are higher above the current model than they are under the suggested model. This shows that under the suggested model, they would move towards the normal range.

However, there are still many other factors to consider, in order to achieve an even more accurate BMI measure of an individual, some are listed below:

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[51] Weisstein, Eric W. "Residual." From *MathWorld*--A Wolfram Web Resource. http://mathworld.wolfram.com/Residual.html

[52] "Mathwords: First Quartile." *Mathwords: First Quartile*. N.p., n.d. Web. 31 Oct. 2013. <http://www.mathwords.com/f/first_quartile.htm>.

[53] "Descriptive Statistics." *Mathematics Standard Level: Course Companion.* Oxford: University, 2012. N. pag. Print.

[54] In Appendix. (lower and upper quartile values are on separate tables)

1. Bone Mass - Each individual has a different bone strength and thickness, thus a different bone mass. Bone mass is considered to be a constant value in the BMI model, assuming that everyone has the same bone mass. However, bone mass varies from person to person, indicating that it is not a constant value. Nevertheless, if an individual has a significantly larger bone mass, the current BMI model categorizes the 'extra' bone mass of the person, as fat. Thus, the chances of the individual with a higher bone mass having a higher BMI, is very likely.
2. Muscle Mass - A similar trend accounts for the mass of the muscle. In the BMI model muscle mass is also a constant value; everyone has the same muscle mass. However, a person who regularly does physical activity will have more muscles, and thus more muscle mass, than a person who does not. Thus, whatever exceeds this constant value, is categorized as fat. Therefore, the chances for an individual with more muscles to have a higher BMI value, is also very likely.
3. Gender - Differences in gender have a significant impact on the BMI value. The BMI model assumes that both genders have the same percentage of fat and muscle in their body, which is not the case. During puberty, men grow more muscles than women while women grow more fat than men. Besides, Trefethen states that women are on average "about 8% shorter than men"[55], which again, affects the validity and reliability of the current model.
4. Volume and % of H_2O in the body - Approximately 75% of our body consists of water. However, there are illnesses and diseases, which may increase or even decrease the water percentage in the body. There are people with less than 75% water in their body, and others with more than 75% water in their body.

There are many more factors to consider, although one major factor that affects the reliability of the calculated obesity rates of today, is the ethnicity. The current BMI formula assumes that everyone on this planet has the same body proportion. That is not true, since not every person grows up in the same environment, with the same food resources or with the same culture. Therefore, for a country to evaluate the obesity rates within their country, it is essential to know which model best suits the body proportion and ethnicity of the people in their country.
The same 100 (height,weight) values of US adults[56] are compared to 100 (height,weight) values of adolescents in Hong Kong[57][58].

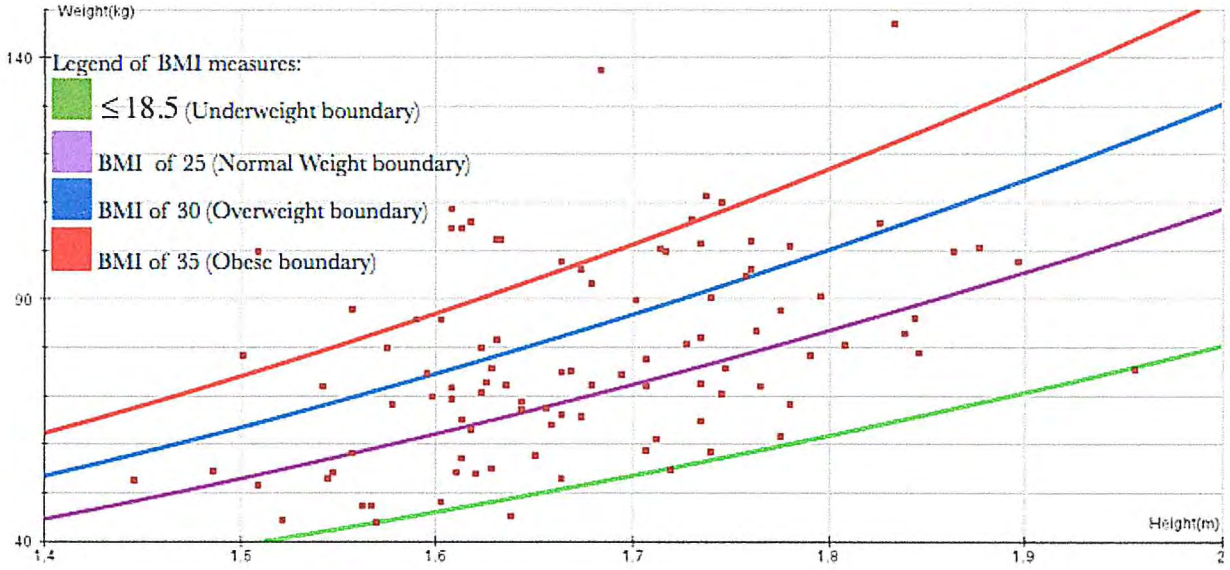
[55] Ibid.

[56] taken from http://www.statcrunch.com/app/index.php?dataid=304881 Op.Cit

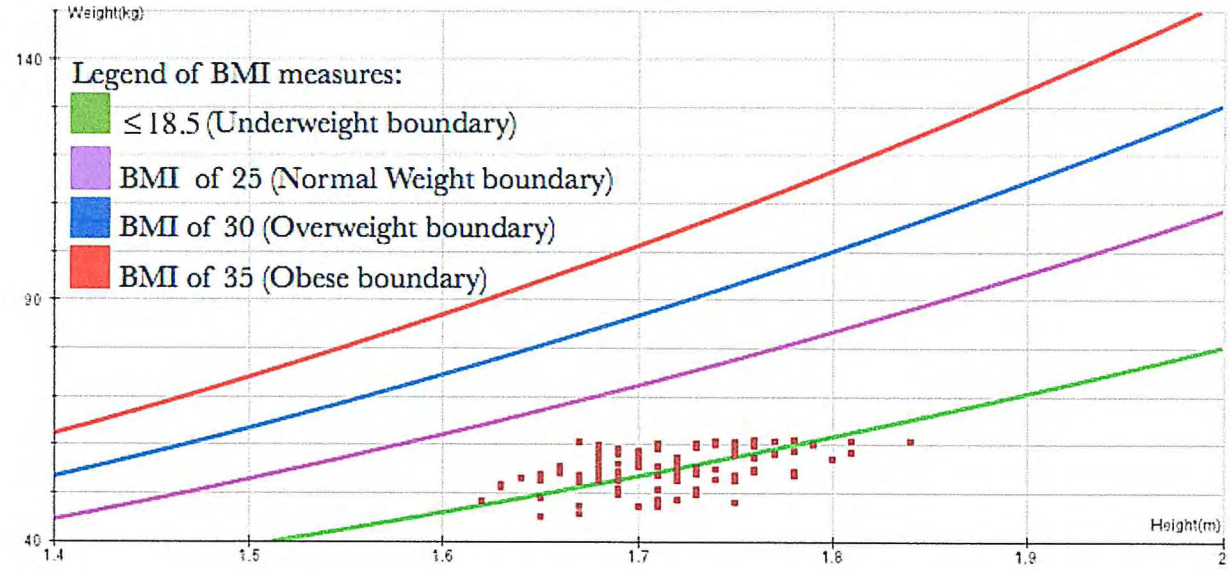
[57] taken from http://wiki.stat.ucla.edu/socr/index.php/SOCR_Data_Dinov_020108_HeightsWeights

[58] In Appendix.

Graph 3: showing the interpretation of the ranges of Trefethen's BMI formula, with processed (height,weight) values from the United States using Trefethen's BMI formula (database: http://www.statcrunch.com/app/index.php?dataid=304881)[59]



Graph 4: showing the interpretation of the ranges of Trefethen's BMI formula, with processed (height,weight) values from Hong Kong using Trefethen's BMI formula (database: http://socr.ucla.edu/docs/resources/SOCR_Data/SOCR_Data_Dinov_020108_HeightsWeights.html)[60]



59 "StatCrunch." *StatCrunch*. N.p., n.d. Web. 04 Jan. 2013. <http://www.statcrunch.com/app/index.php?dataid=304881>.

60 "SOCR Data Dinov 020108 HeightsWeights." *Socr RSS*. N.p., n.d. Web. 29 Oct. 2013.

By sight, there is a significant difference between the two graphs displayed above. In Graph 4, the values do not exceed the normal weight boundary; they lie along the underweight boundary function. This indicates, that the 100 Hong Kong values have either a BMI below 18.5, just 18.5 or above 18.5, meaning that they are either severely underweight, underweight or normal weight. On the other hand, the values in Graph 3 exceed all boundaries. This indicated that there are some who are overweight, obese, and even severely obese. Very few points are below the underweight boundary. More people are above the obese boundary than below the underweight boundary, indicating that there are more obese and overweight people than underweight people of those 100 people.

The chosen databases' height and weight values, display the two extremes there are: overweight-obese and underweight-normal weight. Hong Kong showing the extremes of the underweight to normal weight, while the US showing the extreme from the other end.

However, in analyzing the two graphs, a problem arises. Both values, from Hong Kong and the US, were plotted on the same interpretation of the BMI ranges, thus it is a comparison, where US citizens are compared to citizens from Hong Kong, assuming that the people in the US and Hong Kong have the same body proportions. This does not indicate how large or small people really are, in either of the countries. Perhaps there are points in Graph 4, of Hong Kong citizens, who would appear to the human eye to be overweight or obese but are not according to the BMI measure, simply because their body proportion might not necessarily apply to these ranges. In Hong Kong, a person with a BMI of 24.5 (current BMI) might be described as overweight, whereby globally, they would be categorized as having a normal weight. There are countries that vary very much in interpretations of BMI ranges, therefore it is difficult to come up with a BMI formula which applies to all people on this planet. Nevertheless, if countries decide on interpretations of BMI ranges, which best suit the body proportions of their country, the country and the government would have a more accurate measure of the obesity rates in their country. This surely, is very useful to their economy.

Conclusion

This essay was trying to determine the economic costs associated with obesity, and how authorities can best measure obesity in order to combat it.

In conclusion to the Economics section, the economic costs can be divided into direct and indirect costs; examples of direct costs are preventive, diagnostic, and treatment services related to obesity[61]. Indirect costs can be split into two parts; the morbidity and mortality costs[62]. Morbidity costs are defined as the value of income lost[63] through decreased productivity, bed days, absenteeism and lost income[64]. Mortality costs are expressed as the value of future income lost by premature death[65]. Obesity is costly to both, a national economy and an individual, and since it is a social disease, it is preventable.

In conclusion to the Mathematics part of the essay, the reliability and validity of the current BMI model is limited. Numerous factors, such as bone mass, muscle mass, gender, water % in the body are not considered in the current BMI formula, which makes it difficult to know, whether the BMI value is correct. Trefethen's suggestion of a new BMI formula has helped to approach a more accurate BMI model for tall and small people as demonstrated by the changes in residual values, and thus, to evaluate obesity globally. However, there are still limits to the reliability and validity of the model. Ethnic factors play a significant role, implying that different body proportions are distributed around the world, and thus lead to different interpretations of BMI ranges. This makes it more difficult to calculate obesity rates globally. However a solution would be, that countries individually decide on interpretations of BMI ranges which best fit the body proportions of their country, and develop their own models accordingly, thus making it easier to evaluate whether their country is at high risks of increasing obesity rates.

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61 "Causes and Consequences." *Centers for Disease Control and Prevention*. Centers for Disease Control and Prevention, 27 Apr. 2012. Web. 03 Feb. 2013. <http://www.cdc.gov/obesity/adult/causes/index.html>. op.cit.

62 "Health and Fitness." *Health and Fitness RSS*. N.p., Oct. 2013. Web. 31 Oct. 2013. <http://riskprofiler.info/>.

63 Ibid.

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65 Ibid.

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Appendix

The appendix only contains the raw and processed data used for this research paper.

Table 1: showing raw (height,weight) values of 100 US adults (taken from http://www.statcrunch.com/app/index.php?dataid=304881) with the calculated BMI measures using the current and suggested formula. Additionally, the weight(kg) values if they would have a normal BMI(21.75 specifically) was calculated, and the residual values of both BMI formulae.

Weight (pounds)	Height (inches)	Weight (kg) y values	Height (m) x values	$BMI = \frac{1.3weight}{height^{2.5}}$	$BMI = \frac{weight}{height^2}$	Weight with a BMI of 22.5 - Normal Weight (using current formula)	Residual of $BMI = \frac{weight}{height^2}$	Weight with a BMI of 22.5 - Normal Weight (using Trefethen's formula)	Residual of $BMI = \frac{1.3weight}{height^{2.5}}$
116.4	56.9	52.79869	1.445263	27.33376	25.27723	45.43107	54.28188	42.011	116.3742
120.4	58.5	54.61308	1.485903	26.37934	24.73522	48.02199	43.44247	45.0269	91.89484
173.1	59.1	78.51764	1.501143	36.97051	34.84361	49.01211	870.5766	46.19033	1045.055
220.8	59.4	100.1542	1.508763	46.56505	43.99742	49.51096	2564.74	46.77874	2848.942
114	59.4	51.71006	1.508763	24.04174	22.71606	49.51096	4.836057	46.77874	24.31793
98.1	59.9	44.49787	1.521463	20.25951	19.22279	50.34798	34.22384	47.76936	10.70269
159	60.7	72.12193	1.541783	31.76527	30.34036	51.70182	416.9808	49.38035	517.1795
116.6	60.8	52.88941	1.544323	23.19886	22.17647	51.87231	1.034498	49.58398	10.92591
119.7	60.9	54.29556	1.546863	23.718	22.69136	52.04308	5.073669	49.78811	20.31714
194.4	61.3	88.17926	1.557023	37.89415	36.37277	52.72898	1256.722	50.60968	1411.473
128.5	61.3	58.28722	1.557023	25.04834	24.0427	52.72898	30.89399	50.60968	58.94459
104.5	61.5	47.40089	1.562103	20.20485	19.42527	53.07361	32.17981	51.02349	13.12327
104.5	61.7	47.40089	1.567183	20.04151	19.29954	53.41937	36.22211	51.43933	16.30902
97	61.8	43.99891	1.569723	18.52796	17.85648	53.59267	92.04018	51.64801	58.50871
176.8	62	80.19595	1.574803	33.49887	32.33701	53.94011	689.3695	52.06689	791.2443
151	62.1	68.49315	1.577343	28.49542	27.52927	54.11425	206.7528	52.27709	262.9606
189.4	62.6	85.91128	1.590043	35.03251	33.9807	54.98916	956.1772	53.33573	1061.166
164.9	62.8	74.79815	1.595123	30.25859	29.39696	55.34109	378.5771	53.76275	442.4878
154.1	62.9	69.8993	1.597663	28.16457	27.38435	55.51748	206.8369	53.97703	253.5186
189.4	63.1	85.91128	1.602743	34.34264	33.44431	55.87109	902.4128	54.40713	992.5114
106	63.1	48.08128	1.602743	19.22027	18.71751	55.87109	60.68108	54.40713	40.0163
239.9	63.3	108.8179	1.607823	43.15668	42.09435	56.22583	2765.929	54.83927	2913.695
158.5	63.3	71.89513	1.607823	28.51327	27.8114	56.22583	245.527	54.83927	290.9022
231	63.3	104.7809	1.607823	41.55562	40.5327	56.22583	2357.596	54.83927	2494.167
153.2	63.3	69.49106	1.607823	27.55983	26.88143	56.22583	175.9665	54.83927	214.675
119.7	63.4	54.29556	1.610363	21.44856	20.93711	56.40362	4.443884	55.05611	0.578435
143.5	63.5	65.09117	1.612903	25.61207	25.02105	56.58169	72.41137	55.27347	96.38732
231	63.5	104.7809	1.612903	41.22919	40.27778	56.58169	2323.165	55.27347	2450.987
125.9	63.5	57.10787	1.612903	22.4708	21.95226	56.58169	0.276865	55.27347	3.365012
233.9	63.7	106.0963	1.617983	41.41987	40.52774	56.93867	2416.477	55.70972	2538.812

Weight (pounds)	Height (inches)	Weight (kg) y values	Height (m) x values	$BMI = \frac{1.3 weight}{height^{2.5}}$	$BMI = \frac{weight}{height^2}$	Weight with a BMI of 22.5 - Normal Weight (using current formula)	Residual of $BMI = \frac{weight}{height^2}$	Weight with a BMI of 22.5 - Normal Weight (using Trefethen's formula)	Residual of $BMI = \frac{1.3 weight}{height^{2.5}}$
138.9	63.7	63.00463	1.617983	24.59692	24.06714	56.93867	36.79587	55.70972	53.21565
119	63.8	53.97805	1.620523	20.99048	20.55449	57.11758	9.856666	55.92862	3.804738
155.9	63.9	70.71578	1.623063	27.39183	26.84389	57.29677	180.0697	56.14803	212.2191
176.8	63.9	80.19595	1.623063	31.06399	30.44259	57.29677	524.3726	56.14803	578.3025
160.7	64	72.89304	1.625603	28.12503	27.58398	57.47624	237.6777	56.36796	273.0782
167.3	64.1	75.88678	1.628143	29.16607	28.62733	57.656	332.3615	56.58841	372.4272
121.3	64.1	55.02132	1.628143	21.14671	20.7561	57.656	6.941531	56.58841	2.455768
179.9	64.2	81.6021	1.630683	31.24069	30.68754	57.83603	564.8262	56.80937	614.6797
226	64.2	102.5129	1.630683	39.24623	38.55133	57.83603	1996.025	56.80937	2088.815
225.8	64.3	102.4222	1.633223	39.05922	38.39751	58.01635	1971.881	57.03085	2060.375
159.4	64.4	72.30337	1.635763	27.46634	27.02201	58.19694	198.9912	57.25284	226.5182
99.4	64.5	45.08754	1.638303	17.06138	16.7984	58.37782	176.6314	57.47536	153.4579
151.9	64.7	68.90139	1.643383	25.87165	25.51234	58.74041	103.2454	57.92194	120.5483
148.1	64.7	67.17772	1.643383	25.22443	24.87411	58.74041	71.18814	57.92194	85.66944
127.4	65	57.78826	1.651003	21.4493	21.20038	59.28641	2.244447	58.59571	0.651969
149	65.2	67.58596	1.656083	24.89398	24.64292	59.65181	62.95069	59.04748	72.90552
141.3	65.3	64.09326	1.658623	23.51724	23.2979	59.83493	18.13336	59.27415	23.22379
146.2	65.5	66.31588	1.663703	24.14745	23.95884	60.20202	37.3794	59.72906	43.38631
116.8	65.5	52.98013	1.663703	19.29153	19.14085	60.20202	52.1556	59.72906	45.54797
165.3	65.5	74.97959	1.663703	27.30214	27.08889	60.20202	218.3767	59.72906	232.5787
215.8	65.5	97.88624	1.663703	35.64308	35.36469	60.20202	1420.101	59.72906	1455.97
166	65.7	75.29711	1.668783	27.20957	27.03824	60.57022	216.8811	60.18605	228.3441
212.1	65.9	96.20793	1.673863	34.50279	34.33767	60.93955	1243.858	60.64513	1264.713
145.5	65.9	65.99837	1.673863	23.66882	23.55555	60.93955	25.5916	60.64513	28.65713
144.8	65.9	65.68085	1.673863	23.55495	23.44222	60.93955	22.47989	60.64513	25.35845
159.8	66.1	72.4848	1.678943	25.79884	25.71431	61.31	124.8761	61.10631	129.4702
205.7	66.1	93.30491	1.678943	33.20915	33.10034	61.31	1023.674	61.10631	1036.75
303.4	66.3	137.6213	1.684023	48.61372	48.52768	61.68158	5766.847	61.56958	5783.869
164.2	66.7	74.48063	1.694183	25.91706	25.94911	62.4281	145.2636	62.50244	143.477
198	67	89.81221	1.701803	30.90333	31.01106	62.99093	719.381	63.20762	707.8045
171.3	67.2	77.70117	1.706883	26.53758	26.66981	63.36756	205.4524	63.68037	196.5828
159.2	67.2	72.21265	1.706883	24.66306	24.78595	63.36756	78.23557	63.68037	72.79972
129.4	67.2	58.69545	1.706883	20.04648	20.14637	63.36756	21.82856	63.68037	24.84939
135.1	67.4	61.28096	1.711963	20.7746	20.90916	63.74531	6.073022	64.15524	8.261507

Weight (pounds)	Height (inches)	Weight (kg) y values	Height (m) x values	$BMI = \frac{1.3weight}{height^{2.5}}$	$BMI = \frac{weight}{height^2}$	Weight with a BMI of 22.5 - Normal Weight (using current formula)	Residual of $BMI = \frac{weight}{height^2}$	Weight with a BMI of 22.5 - Normal Weight (using Trefethen's formula)	Residual of $BMI = \frac{1.3weight}{height^{2.5}}$
221.8	67.5	100.6078	1.714503	33.98046	34.22591	63.9346	1344.925	64.39347	1311.479
220.7	67.6	100.1089	1.717043	33.68703	33.95549	64.12418	1294.897	64.63223	1258.591
120.8	67.7	54.79452	1.719583	18.37056	18.53065	64.31404	90.62119	64.87152	101.5459
178.4	68	80.92171	1.727203	26.83179	27.12552	64.88529	257.1667	65.59258	234.9823
235.2	68.1	106.686	1.729743	35.24493	35.65694	65.07627	1731.371	65.83399	1668.888
143.1	68.3	64.90973	1.734823	21.28702	21.56747	65.45907	0.301771	66.31842	1.984392
181.2	68.3	82.19178	1.734823	26.95464	27.30976	65.45907	279.9836	66.31842	251.9636
224.2	68.3	101.6965	1.734823	33.35116	33.79055	65.45907	1313.148	66.31842	1251.605
160.1	68.3	72.62088	1.734823	23.81588	24.12965	65.45907	51.29156	66.31842	39.72106
246	68.4	111.5849	1.737363	36.46044	36.96783	65.65089	2109.93	66.56143	2027.11
129.2	68.5	58.60474	1.739903	19.07933	19.35898	65.84299	52.39239	66.80498	67.24399
199.7	68.5	90.58333	1.739903	29.49027	29.92251	65.84299	612.084	66.80498	565.4098
155.6	68.7	70.5797	1.744983	22.81103	23.17913	66.22804	18.93691	67.29368	10.79794
242.9	68.7	110.1787	1.744983	35.60924	36.18387	66.22804	1931.662	67.29368	1839.127
167.3	68.8	75.88678	1.747523	24.43723	24.84964	66.42098	89.60133	67.53882	69.68839
209.2	69.2	94.8925	1.757684	30.11782	30.715	67.19557	767.12	68.52478	695.2566
212.1	69.3	96.20793	1.760224	30.42529	31.05097	67.38991	830.478	68.77261	752.6969
225.3	69.3	102.1954	1.760224	32.3188	32.98342	67.38991	1211.423	68.77261	1117.084
184.3	69.4	83.59793	1.762764	26.3423	26.90342	67.58454	256.4287	69.02097	212.4877
159	69.5	72.12193	1.765304	22.64447	23.14347	67.77945	18.8571	69.26988	8.134189
136	69.9	61.6892	1.775464	19.09295	19.56976	68.56189	47.23394	70.27087	73.64518
193.3	69.9	87.6803	1.775464	27.13726	27.81497	68.56189	365.5138	70.27087	303.0883
150.6	70.1	68.31171	1.780544	20.99215	21.54716	68.95479	0.413555	70.7746	6.065838
222.7	70.1	101.0161	1.780544	31.04218	31.86289	68.95479	1027.925	70.7746	914.5455
173.1	70.5	78.51764	1.790704	23.78764	24.48611	69.74397	76.97737	71.78855	45.28069
200.2	70.7	90.81012	1.795784	27.31761	28.15959	70.14024	427.244	72.29877	342.6701
177.7	71.2	80.60419	1.808484	23.82399	24.64498	71.13583	89.64982	73.58383	49.28547
233.7	71.9	106.0056	1.826264	30.5748	31.78352	72.54145	1119.851	75.40578	936.3506
324.5	72.2	147.1922	1.833884	42.01446	43.76645	73.14806	5482.539	76.19481	5040.634
183.2	72.4	83.09897	1.838964	23.55625	24.5725	73.55388	91.10891	76.72357	40.64575
190.3	72.6	86.31951	1.844044	24.30101	25.38438	73.96081	152.7375	77.25453	82.17393
174.4	72.7	79.10732	1.846584	22.1941	23.1995	74.1647	24.42949	77.52083	2.516944
220.5	73.4	100.0181	1.864364	27.39653	28.77514	75.59978	596.2563	79.40038	425.0924
222.2	73.9	100.7893	1.877064	27.14314	28.60594	76.63326	583.5122	80.75948	401.1921

Weight (pounds)	Height (inches)	Weight (kg) y values	Height (m) x values	$BMI = \frac{1.3weight}{height^{2.5}}$	$BMI = \frac{weight}{height^2}$	Weight with a BMI of 22.5 - Normal Weight (using current formula)	Residual of $BMI = \frac{weight}{height^2}$	Weight with a BMI of 22.5 - Normal Weight (using Trefethen's formula)	Residual of $BMI = \frac{1.3weight}{height^{2.5}}$
215.8	74.7	97.88624	1.897384	25.6612	27.19013	78.30142	383.5651	82.9629	222.7061
166.4	77	75.47854	1.955804	18.34229	19.73208	83.19742	59.5811	89.49715	196.5214

Table 2: showing the first quartile, 25th percentile (25 values) of the set of data from Table 1

Weight (pounds)	Height (inches)	Weight (kg) y values	Height (m) x values	$BMI = \frac{1.3weight}{height^{2.5}}$	$BMI = \frac{weight}{height^2}$	Weight with a BMI of 21.75 - Normal Weight (using current formula)	Residual of $BMI = \frac{weight}{height^2}$	Weight with a BMI of 21.75 - Normal Weight (using Trefethen's formula)	Residual of $BMI = \frac{1.3weight}{height^{2.5}}$
116.4	56.9	52.79869	1.445263	27.33376	25.27723	45.43107	54.28188	42.011	116.3742
120.4	58.5	54.61308	1.485903	26.37934	24.73522	48.02199	43.44247	45.0269	91.89484
173.1	59.1	78.51764	1.501143	36.97051	34.84361	49.01211	870.5766	46.19033	1045.055
220.8	59.4	100.1542	1.508763	46.56505	43.99742	49.51096	2564.74	46.77874	2848.942
114	59.4	51.71006	1.508763	24.04174	22.71606	49.51096	4.836057	46.77874	24.31793
98.1	59.9	44.49787	1.521463	20.25951	19.22279	50.34798	34.22384	47.76936	10.70269
159	60.7	72.12193	1.541783	31.76527	30.34036	51.70182	416.9808	49.38035	517.1795
116.6	60.8	52.88941	1.544323	23.19886	22.17647	51.87231	1.034498	49.58398	10.92591
119.7	60.9	54.29556	1.546863	23.718	22.69136	52.04308	5.073669	49.78811	20.31714
194.4	61.3	88.17926	1.557023	37.89415	36.37277	52.72898	1256.722	50.60968	1411.473
128.5	61.3	58.28722	1.557023	25.04834	24.0427	52.72898	30.89399	50.60968	58.94459
104.5	61.5	47.40089	1.562103	20.20485	19.42527	53.07361	32.17981	51.02349	13.12327
104.5	61.7	47.40089	1.567183	20.04151	19.29954	53.41937	36.22211	51.43933	16.30902
97	61.8	43.99891	1.569723	18.52796	17.85648	53.59267	92.04018	51.64801	58.50871
176.8	62	80.19595	1.574803	33.49887	32.33701	53.94011	689.3695	52.06689	791.2443
151	62.1	68.49315	1.577343	28.49542	27.52927	54.11425	206.7528	52.27709	262.9606
189.4	62.6	85.91128	1.590043	35.03251	33.9807	54.98916	956.1772	53.33573	1061.166
164.9	62.8	74.79815	1.595123	30.25859	29.39696	55.34109	378.5771	53.76275	442.4878
154.1	62.9	69.8993	1.597663	28.16457	27.38435	55.51748	206.8369	53.97703	253.5186
189.4	63.1	85.91128	1.602743	34.34264	33.44431	55.87109	902.4128	54.40713	992.5114
106	63.1	48.08128	1.602743	19.22027	18.71751	55.87109	60.68108	54.40713	40.0163
239.9	63.3	108.8179	1.607823	43.15668	42.09435	56.22583	2765.929	54.83927	2913.695
158.5	63.3	71.89513	1.607823	28.51327	27.8114	56.22583	245.527	54.83927	290.9022
231	63.3	104.7809	1.607823	41.55562	40.5327	56.22583	2357.596	54.83927	2494.167

Weight (pounds)	Height (inches)	Weight (kg) y values	Height (m) x values	$BMI = \frac{1.3weight}{height^{2.5}}$	$BMI = \frac{weight}{height^2}$	Weight with a BMI of 21.75 - Normal Weight (using current formula)	Residual of $BMI = \frac{weight}{height^2}$	Weight with a BMI of 21.75 - Normal Weight (using Trefethen's formula)	Residual of $BMI = \frac{1.3weight}{height^{2.5}}$
153.2	63.3	69.49106	1.607823	27.55983	26.88143	56.22583	175.9665	54.83927	214.675

Table 3: showing the upper quartile, 75th percentile (25 values) of the set of data from Table 1

Weight (pounds)	Height (inches)	Weight (kg) y values	Height (m) x values	$BMI = \frac{1.3weight}{height^{2.5}}$	$BMI = \frac{weight}{height^2}$	Weight with a BMI of 21.75- Normal Weight (using current formula)	Residual of $BMI = \frac{weight}{height^2}$	Weight with a BMI of 21.75 - Normal Weight (using Trefethen's formula)	Residual of $BMI = \frac{1.3weight}{height^{2.5}}$
199.7	68.5	90.58333	1.739903	29.49027	29.92251	65.84299	612.084	66.80498	565.4098
155.6	68.7	70.5797	1.744983	22.81103	23.17913	66.22804	18.93691	67.29368	10.79794
242.9	68.7	110.1787	1.744983	35.60924	36.18387	66.22804	1931.662	67.29368	1839.127
167.3	68.8	75.88678	1.747523	24.43723	24.84964	66.42098	89.60133	67.53882	69.68839
209.2	69.2	94.8925	1.757684	30.11782	30.715	67.19557	767.12	68.52478	695.2566
212.1	69.3	96.20793	1.760224	30.42529	31.05097	67.38991	830.478	68.77261	752.6969
225.3	69.3	102.1954	1.760224	32.3188	32.98342	67.38991	1211.423	68.77261	1117.084
184.3	69.4	83.59793	1.762764	26.3423	26.90342	67.58454	256.4287	69.02097	212.4877
159	69.5	72.12193	1.765304	22.64447	23.14347	67.77945	18.8571	69.26988	8.134189
136	69.9	61.6892	1.775464	19.09295	19.56976	68.56189	47.23394	70.27087	73.64518
193.3	69.9	87.6803	1.775464	27.13726	27.81497	68.56189	365.5138	70.27087	303.0883
150.6	70.1	68.31171	1.780544	20.99215	21.54716	68.95479	0.413555	70.7746	6.065838
222.7	70.1	101.0161	1.780544	31.04218	31.86289	68.95479	1027.925	70.7746	914.5455
173.1	70.5	78.51764	1.790704	23.78764	24.48611	69.74397	76.97737	71.78855	45.28069
200.2	70.7	90.81012	1.795784	27.31761	28.15959	70.14024	427.244	72.29877	342.6701
177.7	71.2	80.60419	1.808484	23.82399	24.64498	71.13583	89.64982	73.58383	49.28547
233.7	71.9	106.0056	1.826264	30.5748	31.78352	72.54145	1119.851	75.40578	936.3506
324.5	72.2	147.1922	1.833884	42.01446	43.76645	73.14806	5482.539	76.19481	5040.634
183.2	72.4	83.09897	1.838964	23.55625	24.5725	73.55388	91.10891	76.72357	40.64575
190.3	72.6	86.31951	1.844044	24.30101	25.38438	73.96081	152.7375	77.25453	82.17393
174.4	72.7	79.10732	1.846584	22.1941	23.1995	74.1647	24.42949	77.52083	2.516944
220.5	73.4	100.0181	1.864364	27.39653	28.77514	75.59978	596.2563	79.40038	425.0924
222.2	73.9	100.7893	1.877064	27.14314	28.60594	76.63326	583.5122	80.75948	401.1921
215.8	74.7	97.88624	1.897384	25.6612	27.19013	78.30142	383.5651	82.9629	222.7061
166.4	77	75.47854	1.955804	18.34229	19.73208	83.19742	59.5811	89.49715	196.5214

Table 4: [Height and weight values used from http://www.statcrunch.com/app/index.php?dataid=304881 (US data) were given in inches and pounds. Thus;] the following formulas have been used, to convert from inches to meters, and from pounds to kilograms[66] [67].

From inches to meters	From pounds to kilograms
$m = \frac{in}{39.370}$	$kg = \frac{lb}{2.2046}$
Thus; $in = m \times 39.370$	Thus; $lb = kg \times 2.2046$

Table 5: showing raw (height,weight) values of 100 Hong Kong adolescents (taken from http://wiki.stat.ucla.edu/socr/index.php/SOCR_Data_Dinov_020108_HeightsWeights) with the calculated BMI measures using the current and suggested formula.

Height x	Weight y	$BMI = \frac{1.3 weight}{height^{2.5}}$	$BMI = \frac{weight}{height^2}$
1.65	45.09	16.561983471074	16.761532639088
1.67	45.76	16.40790275736	16.505861256048
1.71	47.27	16.165657809241	16.070843749165
1.70	47.32	16.373702422145	16.325473444268
1.67	47.33	16.970848721718	17.072168121694
1.75	48.21	15.742040816327	15.469823619205
1.62	48.44	18.457552202408	18.852109360395
1.71	48.55	16.603399336548	16.506017855341
1.72	48.81	16.498783126014	16.354265453142
1.65	48.99	17.994490358127	18.211299267884
1.73	49.63	16.582578769755	16.389751530088
1.69	49.70	17.401351493295	17.401351493295
1.71	50.74	17.352347730926	17.250573552626
1.73	50.79	16.970162718434	16.772828535426
1.69	50.99	17.853016350968	17.853016350968
1.63	51.28	19.30068877263	19.652706025066
1.63	51.92	19.541571003801	19.897981607282
1.67	52.49	18.821040553623	18.933405973119
1.68	52.61	18.640164399093	18.695558769057
1.69	52.62	18.423724659501	18.423724659501

[66] "Inches to Meters." *Metric Conversion Charts and Calculators*. N.p., n.d. Web. 24 Oct. 2013. <http://www.metric-conversions.org/length/inches-to-meters.htm>.

[67] "Pounds to Kg (lbs to Kilo)." *Metric Conversion Charts and Calculators*. N.p., n.d. Web. 24 Oct. 2013. <http://www.metric-conversions.org/length/inches-to-meters.htm>.

Height x	Weight y	$BMI = \frac{1.3weight}{height^{2.5}}$	$BMI = \frac{weight}{height^2}$
1.75	52.75	17.224489795918	16.926637542275
1.72	52.77	17.837344510546	17.681101986525
1.65	52.78	19.386593204775	19.620175043048
1.74	52.92	17.479191438763	17.226223082988
1.72	53.13	17.95903190914	17.80172348956
1.64	53.23	19.791046995836	20.09047469685
1.72	53.59	18.114521362899	17.95585096566
1.67	53.66	19.240560794579	19.355430834779
1.68	53.68	19.019274376417	19.075795375841
1.69	53.71	18.805363957845	18.805363957845
1.78	53.80	16.980179270294	16.545337182291
1.72	53.81	18.188885884262	18.029564106403
1.71	53.82	18.40566328101	18.297711245611
1.75	53.83	17.577142857143	17.273192396221
1.69	54.02	18.913903574805	18.913903574805
1.65	54.10	19.871441689624	20.110865286641
1.73	54.12	18.082795950416	17.872523731782
1.66	54.33	19.716214254609	19.893575076249
1.69	54.50	19.081964917195	19.081964917195
1.78	54.55	17.21689180659	16.775987793568
1.68	54.58	19.338151927438	19.395620559117
1.76	54.64	17.639462809917	17.285118985705
1.72	54.98	18.584369929692	18.421583991267
1.74	55.05	18.182718985335	17.919568796646
1.76	55.06	17.775051652893	17.417984102359
1.66	55.19	20.028305995065	20.2084742952
1.73	55.32	18.483744862842	18.268810289028
1.71	55.52	18.987038746965	18.875676855376
1.66	55.65	20.195238786471	20.37690876115
1.70	55.65	19.256055363322	19.199336373067
1.72	55.66	18.814223904813	18.64942460811
1.70	55.72	19.280276816609	19.223486481712
1.70	55.89	19.339100346021	19.282136745565
1.68	55.93	19.816468253968	19.875358334031
1.69	56.05	19.624663001996	19.624663001996
1.68	56.23	19.922760770975	19.981966728456
1.70	56.47	19.539792387543	19.48223764577
1.68	56.72	20.096371882086	20.156093772684
1.72	56.72	19.172525689562	19.004587922602
1.68	56.83	20.135345804989	20.195183517307
1.72	56.99	19.263791238507	19.095054049878
1.80	57.23	17.663580246914	17.115352001853

Height x	Weight y	$BMI = \frac{1.3weight}{height^{2.5}}$	$BMI = \frac{weight}{height^2}$
1.76	57.38	18.524018595041	18.151905699117
1.72	57.41	19.4057598702	19.235779136752
1.76	57.42	18.536931818182	18.164559519751
1.70	57.75	19.982698961938	19.923839632428
1.70	57.89	20.031141868512	19.972139849719
1.68	57.99	20.546343537415	20.607402642418
1.75	58.08	18.964897959184	18.636949923323
1.70	58.12	20.110726643599	20.051490206696
1.77	58.19	18.573845319034	18.149244176428
1.69	58.26	20.398445432583	20.398445432583
1.81	58.63	17.896279112359	17.292859354969
1.70	58.69	20.307958477509	20.24814109138
1.78	58.85	18.574043681353	18.098384631558
1.68	58.88	20.861678004535	20.923674212547
1.69	58.99	20.654038724134	20.654038724134
1.69	59.32	20.769580897027	20.769580897027
1.75	59.33	19.37306122449	19.038055078353
1.71	59.44	20.327622174344	20.20839755554
1.73	59.47	19.870359851649	19.639301299503
1.75	59.97	19.582040816327	19.243420917729
1.76	59.98	19.363378099174	18.974404040311
1.74	60.00	19.817677368212	19.530865173456
1.68	60.07	21.283304988662	21.346554177101
1.79	60.07	18.747854311663	18.216645494239
1.68	60.17	21.318735827664	21.382090308576
1.75	60.27	19.68	19.339686154936
1.71	60.30	20.621729763004	20.500780158127
1.71	60.42	20.662768031189	20.541577730581
1.73	60.43	20.19111898159	19.9563305453
1.67	60.67	21.754096597225	21.883972954642
1.75	60.72	19.82693877551	19.484084010747
1.74	60.75	20.065398335315	19.775000988124
1.77	60.79	19.403747326758	18.960174488487
1.74	60.87	20.105033690052	19.814062718471
1.84	61.01	18.020439508507	17.270297537384
1.81	61.04	18.63190989286	18.003686423798
1.76	61.12	19.731404958678	19.335037928373
1.78	61.20	19.315742961747	18.821089880227